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Dust Control in Bag-Filling Operations

By Jon C. Volkwein and Richard D. Gaynor

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute	mg/m^3	milligram per cubic meter
ft	foot	μm	micrometer
ft/min	foot per minute	pct	percent
gal	gallon	pt	pint
h	hour	s	second
in	inch	SCFM	standard cubic feet per minute
lb	pound	wt pct	weight percent
L/min	liter per minute		
μg	microgram		

DUST CONTROL IN BAG-FILLING OPERATIONS

By Jon C. Volkwein[1] and Richard D. Gaynor[2]

ABSTRACT

The Bureau of Mines and many member companies of the Industrial Sand Association have been working in several areas to reduce personal exposure to respirable dust. Areas investigated include ventilation, modification of hardware, moisture addition to the product, and improved housekeeping practices.

Ventilation systems have been devised and shown to contain 100 pct of a tracer gas released within the hood. An industrial clean air island has been developed and shown to reduce dust levels 90 pct at the operator's position.

Modification of hardware on a bag filling machine has been demonstrated to reduce dust 83 pct at the machine operator's lapel. This particular development has been termed a significant advancement in the state-of-the-art of bag filling by industry representatives.

Addition of moisture to dried product materials has been tested with results showing dust reductions of 90 pct are possible. Control of the moisture addition method still needs refinement and costs may be prohibitive.

Dust sampling results clearly show the benefits of housekeeping practices such as building cleaning and vacuum sweeping. Rotation of work schedules is also effective for reducing personal exposure.

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INTRODUCTION

Early it was recognized that better dust control procedures were needed around industrial sand bagging operations. Starting in 1975 the Bureau of Mines entered into a series of cooperative research agreements with members of the National Industrial Sand Association (NISA) to improve dust control procedures associated with the operation of fluidized bagging machines and the conveying, handling, and loading of bagged industrial sand products. The early cooperative work contributed to the development of the NISA handbook on "Guidance and Solutions to Reducing Respirable Dust Levels in the Bagging of Whole Grain Silica Products" (1).[3]

Solutions for bagging fine milled or ground products were much more difficult. Ground silica sometimes referred to as silica flour), is predominately finer than the No. 200 sieve, while whole-grain products are predominately coarser than the No. 200 sieve. Table 1 gives representative ranges in particle size distribution of whole-grain and ground silica products. The industrial sand industry is primarily engaged in operating sand pits and dredges and in washing, screening, and otherwise preparing sand for uses other than construction, such as glassmaking, molding, and abrasives (2). The hardness of the sand or sandstone deposit will determine the method of mining. A loose unconsolidated sand or sandstone can be mined by hydraulic monitoring and pumping in slurry form to a wet processing plant. Hard, consolidated sandstones may require conventional methods of drilling, blasting, loading, and hauling to the processing plant. This material may require one or two stages of crushing to prepare it for wet processing. Wet processing is often required to clean the material and remove clay and other material finer than the No. 140 sieve. Most of the slimes and other fines are removed by hydraulic classification with the fines pumped to a tailings pond to be wasted. Oversize material is removed by wet screening. If the feed material to the wet-processing area is from a hard, consolidated sandstone, wet rod milling in closed circuit with screens, is added at the head of the wet-process circuit to reduce the material to sand-grain size and remove objectionable oversize material. In many cases, in order to meet rigid physical and chemical customer specifications, it is necessary to provide further beneficiation processes prior to drying for elimination of deleterious material.

Material produced meeting the proper screen sizing must be dried prior to shipment. Drying is generally accomplished by either rotary dryer or fluid-bed dryer using natural gas, fuel oil, or propane as fuel. Once sand has been dried, it may be sold directly or used as feed stock for the grinding process.

Dry material meeting the required physical and chemical limits can then be processed into ground silica products. Grinding is accomplished in pebble mills lined with silica block. Grinding media are generally composed of silica pebbles or heavy-density ceramic spheres. Grinding of the material in the pebble mills is in closed circuit with air classifiers in order to produce a specified size product. The ground silica product is then transported to storage prior to loading in bulk containers or as bagged material.

Because of the fineness of ground silica, exposure to respirable silica tends to be excessive when the material is bagged. Often, if not generally, exposure to respirable quartz (or silica) approaches or exceeds the current MSHA permissible exposure limit (PEL) of 0.1 mg/m^3. For this reason, workers generally are required to wear respirators at their work stations when bagging ground silica, stacking, handling, or loading the bagged materials. The principal objective of the studies was to devise methods whereby it would be possible to work without the encumbrance of

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[3]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

TABLE 1. - Representative size distributions of whole-grain and ground silica products

Size designation[1]		Fraction passing indicated sieve, wt pct				
Sieve No.	Opening, µm	Whole grain[2]		Ground		
		Coarse	Fine	Coarse	Medium	Fine
8......	2,360	100	NAp	NAp	NAp	NAp
12......	1,700	95	NAp	NAp	NAp	NAp
20......	850	25	NAp	NAp	NAp	NAp
30......	600	2	NAp	NAp	NAp	NAp
40......	425	1	99	NAp	NAp	NAp
50......	300	NAp	79	NAp	NAp	NAp
70......	212	NAp	45	NAp	NAp	NAp
100......	150	NAp	16	NAp	NAp	NAp
140......	106	NAp	3	62	97	100
200......	75	NAp	1	51	94	99
325......	45	NAp	NAp	33	77	98

NAp Not applicable.

[1]ASTM E 11-81, Specification for Wire-Cloth Sieves for Testing Purposes.

[2]Coarse (No. 8 by No. 30)--AFS Grain Fineness No. 12; fine (No. 40 by No. 200)--AFS Grain Fineness No. 64.

respirators. The paper summarizes efforts made by both government and industry to control dust in bag-filling operations. Broadly, the engineering controls considered include ventilation, modification of the fluidized packing machine, improvements in bag design and construction, and the use of moisture, foam, steam, or charged spray. Also considered are the effects of administrative controls and good housekeeping, which are considered extremely important in reducing silica exposures.

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Special credit is due the members of the NISA Committee on Engineering and Technology who have guided, advised, and performed much of the work reported here. None of this would have been possible without the support and cooperation of the companies they represent.

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John J. Bryant, George W. Bryant Core Sands, Inc.
Timothy P. Bryant, George W. Bryant Core Sands, Inc.
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Douglas Gerner, Walter C. Best, Inc.
Robert L. Hawvermale, Pennsylvania Glass Sand Corp.
Thomas M. Kilroy, Jr., Unimin Corp.
E. Stuart Kirkpatrick, Pennsylvania Glass Sand Corp.
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Earl R. White, Ottawa Silica Co.
Walter O. Wright, South River Sand Co.
Andrew B. Cecala, Bureau of Mines

Special recognition is extended to the following members of NISA and the Bureau of Mines who took an early, active interest in the problems of the silica-bagging industry and whose vision and leadership contributed to the success of this paper: Arnold A. Alekna (deceased) of Martin Marietta Laboratories, Lester C. Richards (retired) of Ottawa Silica Co., and Thomas E. Rosendahl of RET Consulting (formerly with Bureau of Mines).

VENTILATION

An adequate exhaust ventilation system is essential for good dust control around bag-filling operations. To be most effective, hoods should be used to contain and direct the exhaust airflows. General guidelines for hood and duct designs can be found in the Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists (3).

The Bureau designed a new ventilation hood specifically for nozzle-type bag-filling machines (4). The ability of this hood to capture a contaminant generated inside the hood was measured using a tracer gas technique (5-6). The tracer gas, sulfur hexafluoride, was released at a steady rate inside the hood near the bag-and-nozzle interface. Bag filling proceeded normally, and air samples were taken at the operator's breathing zone and at the front of the ventilation hood. Figure 1 shows the tracer gas test equipment, a sample being taken, and the ventilation hoods.

Results of this testing showed that (1) The intake face velocity of these hoods should not be less than 200 ft/min; (2) natural or mechanical airflows should not be directed toward the hoods, (3) the nozzle area of the hood must be correctly sealed, and (4) hoods, ducts, and collectors must be maintained. When working as designed, these ventilation hoods captured 100 pct of the sulfur hexafluoride (SF_6) tracer gas released inside the hood.

Unless conveyor systems that support the bagging operations are properly enclosed and ventilated, they may add to the dust exposure of workers. Under a recent Bureau of Mines contract, Martin Marietta Laboratories (7) studied effective enclosure systems suitable for conveyors that feed product to bag-filling machines. Figure 2 illustrates a wear-resistant skirting design that offers a longer lasting, more effective seal to the edge of the belt. Other design features important for dust control include rock boxes, chutes to reduce free fall, impact idlers, enclosure size, ventilation volumes, and various seals.

The Martin Marietta study showed that when good design principles are used, the exhaust air volume requirements for transfer points can be minimized. Results obtained using good engineering designs and exhaust volume estimates have shown that dust from a conveyor-belt transfer point could be reduced by 95 pct.

Large volumes of exhaust ventilation air require that an equal volume of make-up air be supplied to the area. The quality of the background air then becomes important when evaluating worker dust exposure. Emission-rate-sampling data show that the background dust levels in both whole-grain and ground silica bagging operations can contribute to more than one-half of the total respirable dust exposure of a worker. For example, table 2 shows area dust measurements in the intake air and at the work station of a ground-silica bagging machine, prior to installation of dust controls. On the first day, 75 µg of quartz was in the intake air. The worker station was exposed to 118 µg of respirable alpha-quartz. On the following days, the intake levels of quartz were more than one-half of the quartz present at the worker station.

TABLE 2. - Area background respirable alpha-quartz (RAQ) levels versus area samplers at work station

	RAQ level, mg/m^3	
	Intake	Work station
Day 1	0.073	0.118
Day 2	.313	.607
Day 3	.246	.399

FIGURE 1. - Sulfur hexafluoride testing of ventilation hoods.

FIGURE 2. - Wear-resistant skirting design.

Clearly, improvement of the exhaust ventilation system on the machine itself would not achieve compliance for two of the three days at this location. Even if the machine were dust-free, it would still be difficult to comply with the standards for alpha-quartz because the background dust levels were so high. This is not an isolated case. Significant levels of background dust have been encountered in most whole-grain and ground silica mills. This dust entered the work area from locations and operations outside of the bagging areas.

Factors that can account for high background dust levels include the following:

- Meteorological conditions (amount of precipitation and wind speed and direction), which can directly effect fugitive dust sources, such as haulage roads and stockpiles outside the building.

- The proximity of other dust operations where personnel do not normally operate or are in controlled booths, such as the grinding mills found in plants. Open transfer points within the same building or bulk loading facilities immediately adjacent to the building and poor housekeeping also contribute to background dust levels.

- Location of exhaust stacks, which may be such that fans used for ventilation recirculate dust into the building and contribute to the background dust problem. Particulate from stacks that comply with environmental standards can recirculate a high fraction of respirable dust and become a significant background source.

- The overall topography of the plant site.

Because of low threshold limit values, background dust levels are very important. Protecting the operators from background dust may involve three basic approaches:

- Defining the specific background source and controlling it.

- Isolating the bagging operations from possible background dust sources and/or locating the dust sources away from the bagging operations.

- Providing the operator with a source of clean makeup air, either by locating the air inlet away from the dust source or by filtering. The ACGIH Ventilation Handbook (3) provides guidelines for makeup air systems.

A filtration approach was taken at a whole-grain bagging operation where dust from an adjacent bulk-loading facility was being drawn into the bagging building by the exhaust ventilation system of the bagging machine. The company, in consultation with the Bureau of Mines, engineered and installed ventilation hoods, a nozzle cleanout system, and a makeup air ventilation system. Respirable dust levels at the new installation were in compliance as measured by the Mine Safety and Health Administration (MSHA), U.S. Department of Labor. Experience has shown that all three dust control methods must be maintained to stay in compliance.

Another approach that has been tried to control background dust levels involved the ionization of air. In theory, air ionization charges dust particles so that they are electrostatically attracted to an oppositely charged surface. Two separate industrial sand plants have experimented with the Apsee[4] air ionization system but have reported no dust reduction with its use. At one plant, the manufacturer suggested that a second unit was needed to deliver an additional

[4]Reference to specific equipment does not imply endorsement by the Bureau of Mines.

volume of ionized air, but this, too, was unsuccessful. The plant personnel concluded that the exhaust ventilation system in the plant removed the ionized air before it had a chance to become effective.

Since it can be expensive to supply large volumes of conditioned makeup air, the Bureau of Mines has been experimenting with an overhead air supplied island (OASIS) for mills. This device supplies 5,000 cfm of clean air to the workers' breathing zone and may reduce the volume of clean makeup air normally required. The concept is based on a canopy air curtain (8-9) developed earlier for continuous-mining machines. Figure 3 shows a working laboratory model of the OASIS makeup air system. The access covers are removed to show the fan and motor, which bring air into the top filtration panels through the fan and out through the final panel filters through the bottom of the unit. In laboratory tests, respirable dust concentrations were measured outside the canopy air curtain system and 2 ft beneath the canopy, using a real-time aerosol monitor. Four 8-h tests were conducted: two at high concentrations and two at low concentrations. Results in table 3 show that the average efficiency was 89 pct for the unit. Field tests on this system are scheduled.

TABLE 3. - Laboratory results from using the OASIS in mills

Dust concentration, mg/m^3		Dust reduction, pct
Outside	Inside	
6.50	0.63	90
3.60	.48	87
.53	.08	[1]83
.52	.02	95

[1]New filter (initial efficiency of filter is expected to be low until dust cake builds on filter).

FIGURE 3. - Laboratory model of overhead air supplied island (OASIS).

The area where bagged material is loaded into vehicles is a final location where good ventilation is required. The last step of the bagging operation is often the stacking of bags inside a closed vehicle. Dust adhering to the bag surface, leaking bag valves, and broken bags all can contribute to dust generation inside the vehicle. Without proper ventilation, these sources are cumulative and can result in high exposures. In an attempt to provide ventilation inside a van-type trailer, one company suspended a section of flexible tubing into the trailer and blew about 3,000 cfm of air into the truck. No respirable dust data were taken, but workers and officials claimed that the high-velocity jet aerosolized more dust from surfaces than it removed from the vehicle. Use of the system was discontinued. The Bureau plans to conduct some laboratory tests to study how to introduce air into a closed vehicle without creating excessive turbulence.

HARDWARE DESIGN

Good hardware design that prevents dust from being generated is preferable to remedial attempts to capture the dust from the air. Problem areas in bag filling, such as blowback and "rooster tails" (fig. 4), are very difficult to control with exhaust ventilation.

Early attempts to control the blowback (venting of air and product from the bag valve-fill tube interface) of fluidized product through the bag valve involved the use of inflatable bladders, tapered sleeves, and reshaping the fill nozzle. The inflatable bladder approach is

FIGURE 4. - Typical rooster tail during bag filling.

effective in preventing blowback, but few operators have been able to maintain the fragile bladders. Round tapered sleeves and elliptical filling nozzles, which better approximate the shape of the bag valve, are much more durable (fig. 5). However, these are not totally effective in controlling blowback.

FIGURE 5. - Elliptical nozzle on bag-filling machine.

The rooster tail that results from the product and fluidized air pressure in the bag is an extremely difficult problem to solve. Exhaust ventilation is not effective in capturing this release of material because it is thrown outside of the ventilation range. In whole-grain sand, a simple blast of compressed air in the nozzle after the bag was filled was sufficient to prevent the rooster tail (1). However, this approach has been ineffective with finer products such as ground silica.

St. Regis Packaging Machinery Group, the Bureau, and an industrial sand plant experimented with a novel three-way rotary valve manufactured by St. Regis (10). The valve provided a vent for excess product and air at the end of the fill cycle. However, products still remained in the tip of the fill tube and spilled as the bag left the machine. This spillage was successfully controlled by using a short jet of compressed air at the tube-and-bag interface while simultaneously venting the bag. Technically, this system is effective in eliminating the rooster tail, but the rotary valve, which is expensive, would have insufficient durability in contact with abrasive products. An attempt to develop an alternative valve was not successful.

One industrial sand company has developed a "duck bill" filling tube designed to reduce or eliminate the rooster tail and blowback. The patent is pending on this development and full details are unavailable. The filling tube was reported to be only partially successful, since the rooster tail and blowback were not eliminated.

Champion International Corp. has been experimenting with a new fill tube design to solve some of the bagging problems. The company's purge and vacuum system will reduce product loss due to spillage during bag discharge, and complement a new commercially available siftproof bag valve, which will be discussed later. Although the new fill tube is not specifically designed to reduce dust generation, any reduction in spillage should reduce dust levels. Details on this development will be available when system testing is completed.

The Bureau of Mines, through a contract with Foster-Miller, Inc., has devised a bag-filling nozzle that reduces blowback and eliminates the rooster tail (11). Industrial representatives consider this new nozzle to be a significant advance in the state-of-the-art of bag filling. The system (fig. 6) has three unique features: First, a new bag clamp applies uniform pressure for about 270° around the top of the bag valve. This greatly reduces blowback and allows excess air to vent through the bottom of the bag valve. Second, another tube around the fill tube evacuates product material in the nozzle-and-valve area after the bag is full. This relieves the fluidizing air pressure within the bag and eliminates the rooster tail. Third, the exhaust remains on for approximately 2 s as the bag discharges from the machine and vacuums the bag valve clean.

FIGURE 6. - New nozzle for bag filling.

The new system was retrofitted on a four-tube ground silica-packing machine. To determine the dust reduction effectiveness of the new hardware before and after installation, dust surveys were conducted using real-time aerosol monitors (RAM) and gravimetric samplers. Each product grade was sampled on an individual basis (since finer grained products are generally dustier). The RAM instruments were especially useful for this purpose.

Figure 7 shows a section of RAM strip chart for a typical test. This compares dust levels during the bagging of 325-mesh silica with the old nozzle system and the dust levels after installation of the new nozzle system. Dust measurements were taken at the operator's lapel. The average reduction measured for 325-mesh product size was 83 pct. Equivalent dust reductions were measured at other locations and results are shown in table 4.

TABLE 4. - Average RAM results during bagging of 325-mesh ground silica

Location	Normal levels, mg/m^3	Levels with new nozzle, mg/m^3	Difference, pct
Exhaust duct from rear of machine...........	>200.00[1]	21.87	>89
Bag conveyor to dock conveyor transfer point	.33	.13	61
Bag room air intake (from loading dock area)	.29	.06	79
Bag machine operators lapel.................	.42	.07	83
Bag room background level...................	.32	.07	78

[1]RAM off scale.

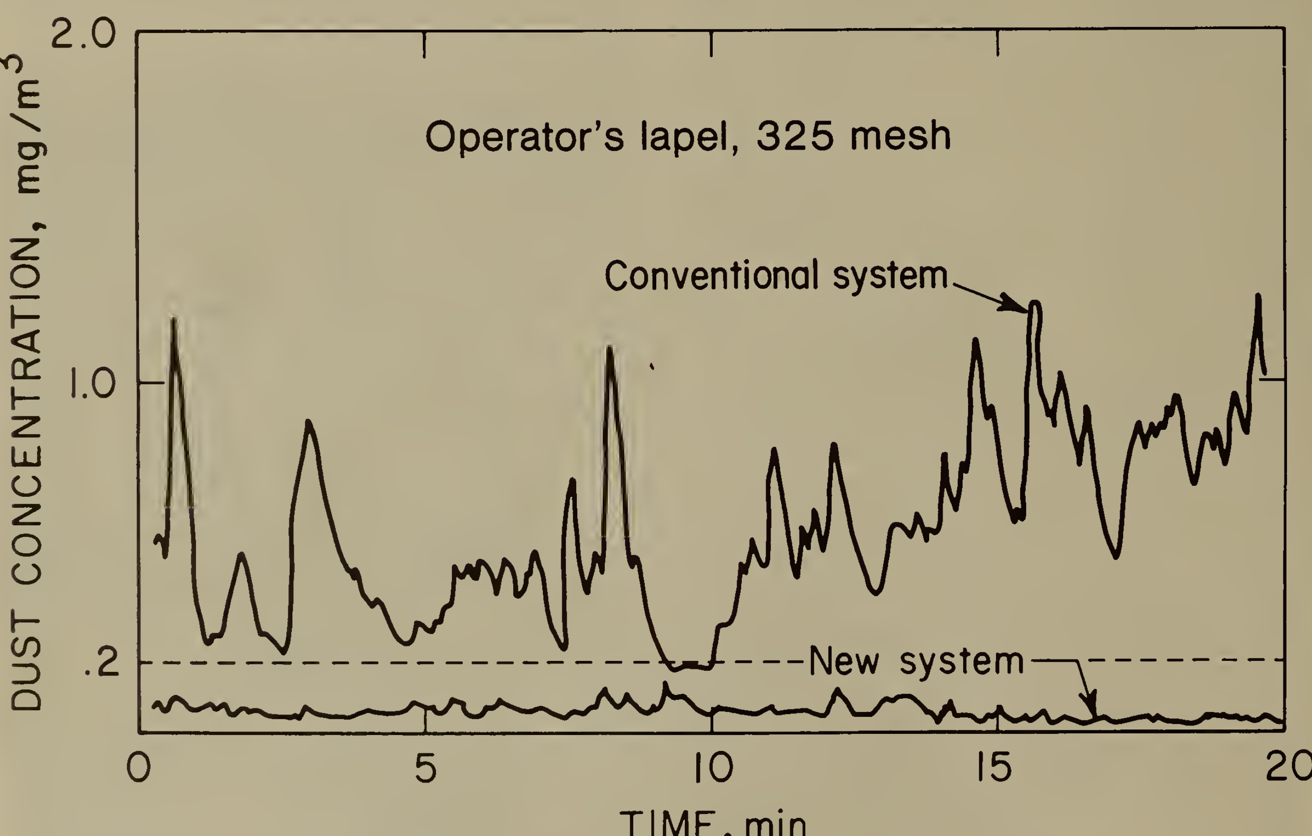

FIGURE 7. - RAM strip chart showing dust levels using new nozzle and conventional nozzle. (Dashed line is threshold limit value.)

The new filling hardware does use a time delay to clean the fill nozzle. The addition of a 7-s time delay did not have a significant effect on productivity. Figure 8 shows that an extra 7-s delay per machine is actually distributed over the fill time of four machines:

$$\text{Delay per bag} = \frac{\text{Time delay per machine}}{\text{Number of machines}}$$

$$= \frac{7}{4} = 1.75 \text{ s.}$$

Actual timing of the old and new hardware (table 5) confirms that the new hardware adds about 1.5 s to the bag-filling cycle on a four-station machine. Other productivity considerations that were not quantified include reduced cleanup around the machine, reduced product loss, less baghouse dust loading, cleaner bags, and cleaner workers. Foster-Miller, Inc., is now marketing this new hardware and has applied for a patent. As testing of the system continues, some areas of wear and maintenance of equipment are being noted. A second unit recently installed corrected some of the inherent problems encountered in the first unit. The performance and operation of the Foster-Miller bagging system will continue to be improved.

TABLE 5. - Field time study of new self-cleaning nozzle

Product grade, mesh	Actual time to fill 50 bags, sec	Additional time per bag, sec	Additional time to load truck with 480 bags, min
120....	70	1.4	11:12
180....	83	1.6	13:17
325....	76	1.5	12:00

Once product material is packaged, the objective is to prevent spillage and bag breakage. The design of the bag valve plays an important role in reducing spillage during bag handling. The basic bag valve consists of a 3- to 5-in tube of kraft paper inserted into the bag. This tube or sleeve receives the nozzle during the filling cycle and collapses when the bag falls onto the discharge conveyor. Product material is frequently

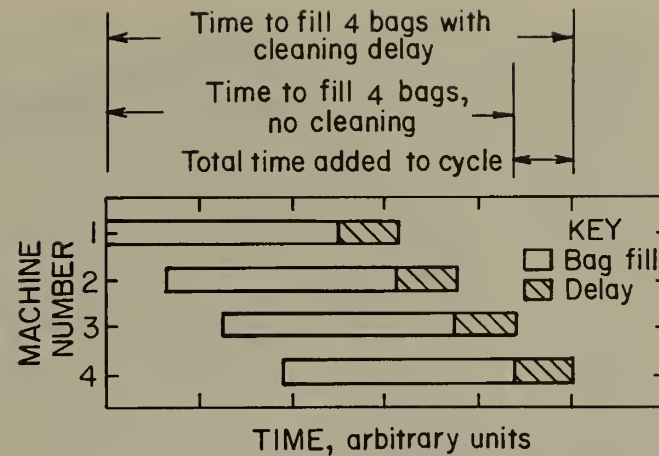

FIGURE 8. - Sequence of machine operation showing effect of cleaning-time delay.

trapped within this sleeve and, as the stiff kraft paper flexes during handling, product dribbles from the bag valve. A better bag valve uses a thin polyethylene tube in place of the kraft paper. This design still traps product within the tube, but the flexible plastic is less prone to flexing open and spillage is reduced, although not eliminated.

Foster Miller attempted to develop a mechanical bag valve seal that was compatable with existing bag-manufacturing equipment (11). Their idea used a two-component sleeve where a stiff preformed plastic acted like a spring to draw a more flexible plastic sleeve closed. In shipment to the plant, it was found that the preformed plastic sleeve lost its shape and did not perform as designed.

Champion International Corp. recently introduced a unique leakproof polyethylene bag valve (called "Sift Proof Valve"), which consists of a sealed tube with a slit facing the bottom of the bag (fig. 9). During filling, the polyethylene valve opens to direct the flow of product downward to the bottom of the bag. The force of the product flow stretches the polyethylene during filling. The stretched polyethylene then overlaps after the bag leaves the machine. Preliminary reports suggest that the sleeve does help to reduce spillage. A patent has been issued on this development.

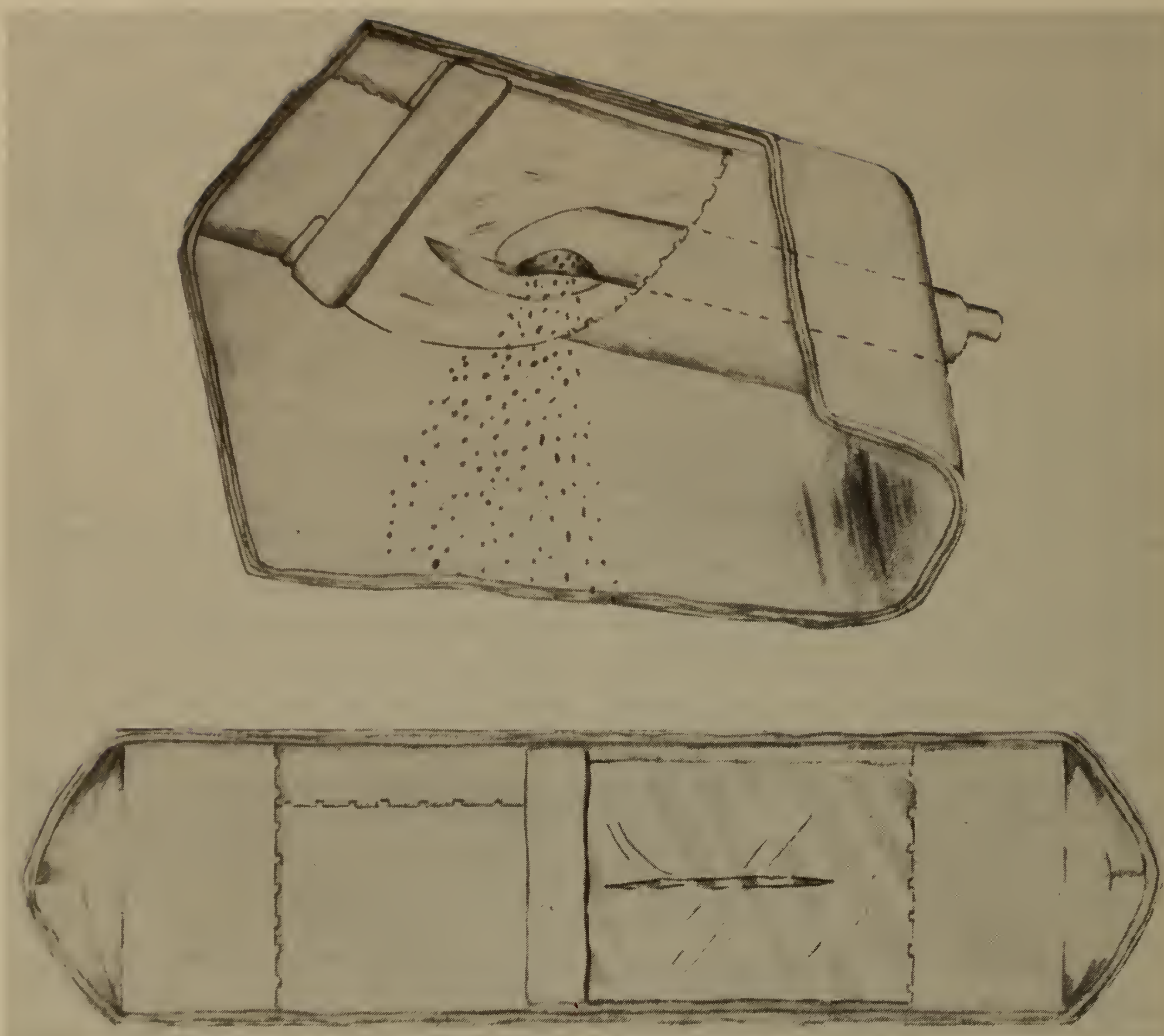

FIGURE 9. - New leakproof polyethylene valve.

Bag breakage can be a substantial source of respirable dust, especially with fine product sizes. Use of stronger bags can reduce breakage and customer complaints while increasing productivity. The records of one company (table 6) indicate that the frequency of broken bags can be reduced when a new three-ply, 50-lb tension-free-dried paper (also called "free-dried" paper) is used instead of a standard three-ply, 60-lb natural kraft paper. Free-dried paper gets its increased strength and resiliency from the fact that it is allowed to stretch in two directions rather than one when being manufactured. Bag breakage was reduced by a factor of 12. Based on the record, this industrial sand plant now specifies this type paper and finds the cost to be comparable to the previous type.

TABLE 6. - Operators record of bag breakage using free-dried and natural kraft paper bags

Paper	Product	Number of bags loaded	Number of bags broken	Breakage, pct
Free-dried.....	Sand.........	8,540	5	0.06
Natural kraft..	...do........	7,080	30	.4
Free-dried.....	Flint........	4,420	1	.02
Natural kraft..	...do........	2,250	15	.7
Do...........	Ground silica	2-530	29	.4

WATER USE

Use of water in a bagged, dry product to control dust has not been widely practiced in the past. However, its use has been reexamined as a means of reducing worker exposure and simplifying complex engineering and administrative controls that are often required. Naturally, water cannot be used (1) with materials that react chemically, (2) or in materials where its use produces handling problems, or (3) where it is unacceptable to the customer. However, there appear to be a number of applications where water can be of benefit in reducing dust levels.

Water can control dust two distinct ways. First is *suppression*, which works by wetting product materials and causing the dust to adhere to the product or other dust particles; this prevents it from becoeing airborne. The second is *airborne capture*, in which water droplets collide with dust particles in the air, increasing their size and causing them to drop from the airstream. Most of the following experiments using water were designed to suppress dust rather than to capture it from the air.

Early work conducted in an industrial laboratory studied the effects on flowability and dust suppression by adding various quantities of water to 325-mesh silica. All samples were uniformly blended in a zig-zag blender (continuous feed). The flowability of the silica was then graded on a scale of 1 to 5, with 5 being optimum. Samples were then dropped from a height of 4 ft onto a paper placed on a black surface. The resulting dust cloud was judged by a three-person panel and graded 1 to 5, with 5 being the least dusty. The results of this study are summarized in table 7. From a material-handling viewpoint, no more than 1 to 2 pct moisture should be added. It appears that some moisture can help the flowability of the sand by removing the static charge found in the totally dry sand. Dust suppression did not occur, however, until moisture rose over 3 pct.

TABLE 7. - Effect of water on flowability and dustiness of 325-mesh ground silica

Sample	Added water, wt pct	Flowability, grade[1]	Dustiness, grade[2]
1	0	1	1
2	1	5	3
3	2	4	3
4	3	2	5
5	4	1	5
6	5	1	5

[1]Grades 1-5; 5 is best flow.
[2]Grades 1-5; 5 is least dustiness.

The recent Bureau of Mines contract with Martin Marietta Laboratories (7) studied wet collection-and-suppression systems on a roll crusher to belt transfer point in a crushed limestone plant. Although this plant was not producing dried mineral product, the results are applicable to dried minerals operation. Martin Marietta measured the dust control achieved using air-atomized water sprays at the crusher discharge and a simple hydraulic water spray at the crusher inlet. The results showed that the water added as a mist, after crushing, was 55 to 65 pct effective in collecting respirable size dust. Adding water to the ore before crushing and allowing it to mix

thoroughly within the crusher suppressed respirable dust 70 to 80 pct. Using both systems together the effectiveness increased 80 to 95 pct.

Two facts of interest from this study are that mixing water with the ore in the crusher provides good dust suppression, and that even the best airborne dust capture spray (air atomizing)[6] did not have sufficient contact time with the dust to be most effective.

In the past, researchers have tried various types of foam to suppress dust in coal mines (13-14), spraying foam on top of the coal much like water spray. The results showed that foam was not much better than a good water spray under the test conditions. New interest in foam systems for minimal moisture addition to dried products, combined with manufacturers claims of superior dust control using foam, led the Bureau to test the effectiveness of foam at two industrial sand plants. These studies differ from previous work in that the foam was thoroughly mixed into dried product materials.

Results in table 8 show that as foam is mixed with 30-mesh glass sand from a transfer point to transfer point, its dust suppression effectiveness increases. Additional testing using more foam showed dust reduction of 80 to 90 pct on three separate occasions at two different plants (15) that process whole grain sands. Limited work has been conducted on the applicability of foam in ground silicas. Although visual tests have indicated that foam has good potential, no quantitative studies have been conducted. Before foam can be considered as a dust control for whole-grain or ground silica, the following must be considered:

- The foaming surfactant must be compatible with the end uses of the product. Ultrapure grades of certain products cannot tolerate even a few parts per million of surfactant.

- Foam generators must be easy to control and regulate. This is especially critical if minimum moisture levels on the order of a few tenths of a percent are to be maintained.

- Evaporation reduces the effectiveness of treatment. This is more likely to be a problem at high product temperatures.

- Foam is relatively expensive. The average amount of surfactant per ton of sand treated was 0.012 gal. At a surfactant cost of $7.25/gal, the cost to treat each ton of sand is $0.09 (exclusive of capital and power costs). Depending on usage, this number can vary from a low of $0.04/ton to a high of $0.20/ton.

[6]For details on the comparison of spray nozzle effectiveness for airborne capture, see Bureau of Mines Technology News 150 (12).

TABLE 8. - Dust reductions as foam is mixed at transfer points

Location and condition	Av. of 4 filters, mg	Std. dev. of 4 filters	Dust reduction, pct
Transfer point 1:			
No foam	7.41	1.83	19.7
Foam	5.95	.87	
Transfer point 2:			
No foam	5.59	.10	32.7
Foam	3.76	.05	
Bulk loadout:			
No foam	6.69	.29	65.3
Foam	2.46	.10	

Foam appears to work by uniformly adding small amounts of water to the dried product material. The surfactant used to generate the foam has no measurable effect on dust suppression, but is only necessary to increase the surface area of the water, thus distributing it uniformly into the product.

Studies showed that the important dust-suppressing properties of foam are the addition of moisture, large water surface area, and good mixing with the dusty materials. Since none of these properties is unique to foam, the Bureau decided to try fine mist sprays and steam for dust suppression (16). Previous work by the Bureau with steam had focused on airborne collection rather than on suppression (17). The new experiments were conducted at two industrial sand plants where an engine-cleaning-type generator made steam, which was added whole grain sand and mixed at a conveyor belt transfer point. Results showed that for an equivalent amount of water, steam was twice as effective as water in suppressing dust. Even with poor mixing and the preliminary nature of these tests, average dust reductions using steam were about 65 pct when adding 0.22 wt pct moisture. Steam will not contaminate the product material and is easily controlled; however, detailed engineering will be required to design a mixing system to prevent condensation and material buildup. The heat needed to make the steam also can be expensive; estimates range from \$0.06 to \$0.08/ton of material.

A use of water in bagging operations was tried at an industrial sand plant, where a company-designed air-atomized spray system was used to wet the nozzle area of the bag during filling and transport. The company also experimented with injecting water into a ground silica product as it flowed into the bag. The Bureau monitored the resulting dust reductions (18). Generally, these methods reduced dust by about 50 pct, but of equal significance was the fact that wetting the bag valve during filling reduced dust levels by 50 pct inside rail cars where the bags were being palletized. Injection of water into the product was discontinued after the experiment because of customer complaints regarding frozen shipments of sand. Currently, the outside surface of the bag is still being wetted.

Foster-Miller, through Bureau of Mines contract (19), compared the effectiveness of using electrically charged water sprays and uncharged water sprays for airborne capture of dust. Figure 10 shows that, regardless of the charge or type of dust, charged sprays were superior to uncharged sprays. Charged water sprays were found to--

- Be the best per unit use of water for airborne capture of dust.
- Require a long residence time with the dust to capture it.

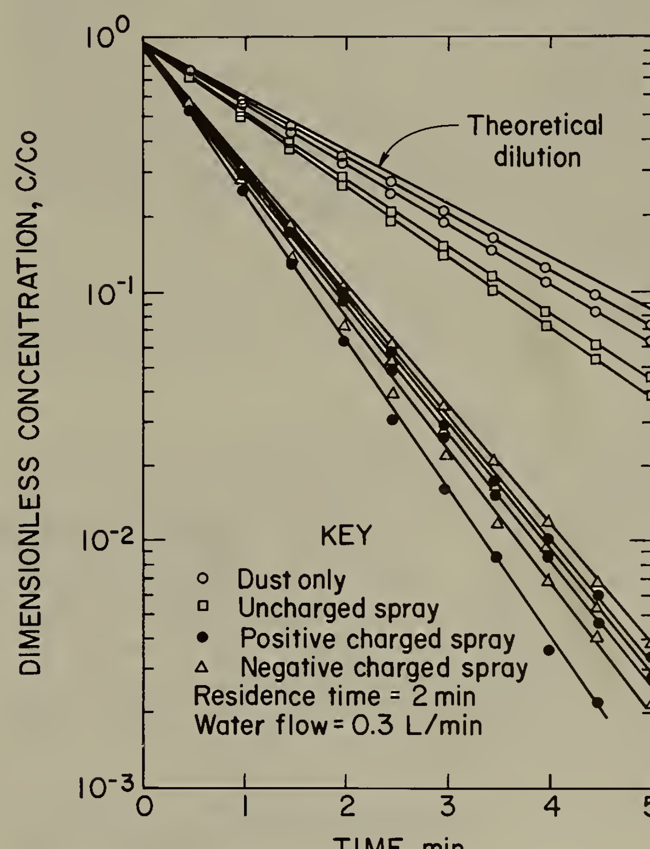

FIGURE 10. - Effect of charged-water sprays on dust concentration in dust box.

- Need water free of suspended solids.
- Not able to be used where static electrical sparks are a hazard.

Using water for dust control for dried mineral products is still in the experimental stage, but results to date indicate that it is potentially an effective tool for the dust control engineer to consider.

WORK PRACTICES AND HOUSEKEEPING

The best engineering technology cannot keep plant dust levels low if the workplace is not kept clean and orderly. In much the same way as a strong safety program requires education and support from management, a strong housekeeping program requires the same commitment. The following work and housekeeping practices are essential to good dust control.

Removing accumulations of dust from floors and ledges in the work area reduces the amount of dust that can become airborne through vibration or wind currents. The data in table 9 compare respirable dust from work area samples taken in a screen tower before and after cleanup. The cleanup reduces exposures by 75 pct of their before-cleanup level. In this instance, the exposure is still high and would require the use of respirators.

TABLE 9. - Effect of cleanup on dust samples

	Before clean-up	After clean-up
Sampling period........h..	4.0	5.5
Total respirable dust..............mg/m^3..	6.69	1.40
Respirable quartz..mg/m^3..	1.46	0.35

Use of brooms and shovels to clean up spills and broken bags must be avoided since large amounts of dust will be generated. Figure 11 shows the exposure of a bag machine operator when a worker on the floor below was using a broom to clean up. Vacuum systems represent the preferred method of cleanup. Although available performance data are limited, most vacuums are centrally located systems that can service large areas throughout a plant. One satisfactory

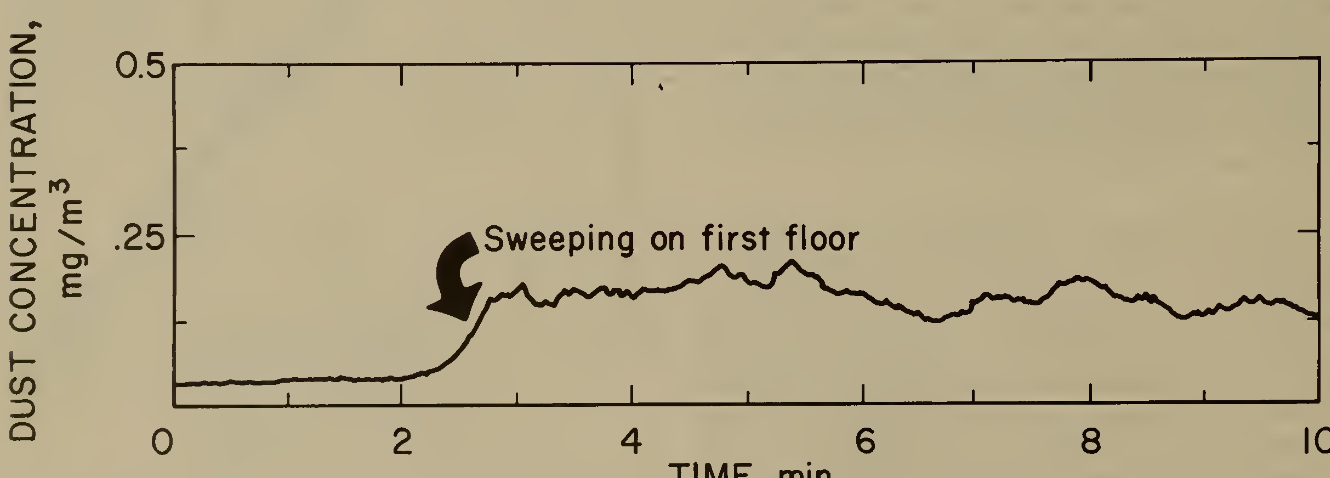

FIGURE 11. - Effect of broom sweeping on bag-machine operator's exposure.

system produces 600 SCFM at 8 in Hg. This system is used for general housekeeping, and to clean up equipment prior to maintenance operations. However, because it is slow picking up broken bags of material, and a larger system is recommended for this application.

Many new plants are being designed for washdown. This design includes proper drainage and protection of the electrical system. In some cases, plants have been able to retrofit existing buildings for washdown. In cases where washdown is not possible, floors have been mopped or sprayed with mineral oil products to help capture and retain dust that collects.

Dust exposures are often high where bags are manually handled, stacked, or palletized. When pallets are loaded into enclosed spaces such as box cars or enclosed trailers, exposure can be high. Box cars and trailers should be cleaned with a vacuum before loading. Spills and broken bags must be cleaned up promptly. When bags are palletized manually, workers should place the bags rather than throw them.

Workers' practices in caring for their work clothes and personal cleanup after work deserve attention. Air hoses must not be used since such use resuspends dust in the air and is inherently dangerous. Although use of company-supplied uniforms is not widespread in the industrial sand industry, it has been used as a part of a program of company relations and good housekeeping in some bagging industries.

MSHA requires posting and the use of respirators in all work areas where respirable quartz exposures exceed the permissible exposure level of 0.1 mg/m^3. By rotation of work assignments, it is often possible to minimize workers potential exposure. Workers bagging or loading ground silica might rotate jobs with workers bagging whole-grain silica or performing other duties.

An essential ingredient of good housekeeping and good work practices is an organized program that starts at the highest levels of company management and makes each level responsible for the one below it. Consequently, the plant manager and shift supervisor bear primary responsiblility, but they must have the support of top management.

Housekeeping duties must be performed on a timely basis. Spills and broken bags must be cleaned up right away. Depending upon conditions, other areas may need to be cleaned daily, weekly, or even monthly. As a part of this regular housekeeping, the ventilation system must be maintained on a regular preventative maintenance schedule. Air velocities at pickup points should be checked on a regularly scheduled basis just like other maintenance checks are made on such items as blowers, controls, materials-handling equipment, gates, valves, and vehicles. Leaks and obstructed ducts must be detected before system performance suffers.

The dust in the air around the plant constitutes a significant proportion of the total dust exposure. Although ground silica is 100 pct quartz, the quartz content of respirable dust samples taken around bagging operations is frequently less than 50 pct and sometimes as low as 10 or 20 pct; the remainder is background dust.

Significant amounts of background dust can come from the discharge of ventilation systems, bag houses, and wet scrubbers. Careful attention to the location of ventilation discharges and the discharge from dust collection equipment can help reduce background dust levels. In one instance, extending stack heights to 1-1/3 times the height of adjacent buildings (fig. 12) placed the discharged dust above the natural turbulence that is developed around and downwind from the building, background dust levels were significantly reduced.

FIGURE 12. - Stacks to remove dust from plant dust-collector discharge.

Unpaved roads and worked out portions of pits are potential sources of background dust. Unpaved roads can be sprayed with water and/or commercial dust treatment compounds. Water is an economic solution only on temporary roads. The commercial treatment compounds are better in areas of moderate rainfall. Paved roads and parking areas may require the use of an ordinary street sweeper or automatic sprinkling system to keep them clean. A program of reclamation by planting may be used to avoid excessive pollution from runoff and will help control potential dust during dry periods.

SUMMARY

Dust levels in the packaging areas of plants that process dried mineral products can be difficult to control. Three primary dust control techniques are available: (1) Ventilation of the area (both exhaust and clean makeup air), (2) redesign of hardware to produce less dust, and (3) careful addition of water (under the proper circumstances). Administrative controls can be used to reduce a workers time in a dusty area and reinsure that the workplace is kept clean and orderly. The techniques summarized in this paper and described in detail in the references cited can be effective in reducing dust exposure in the bagging of industrial mineral products.

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